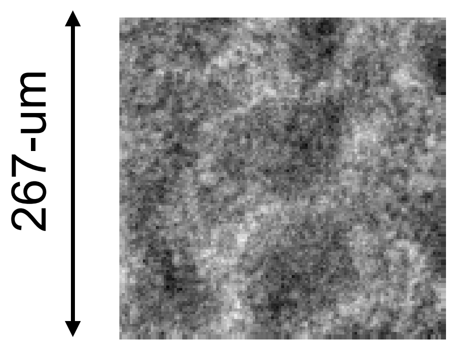
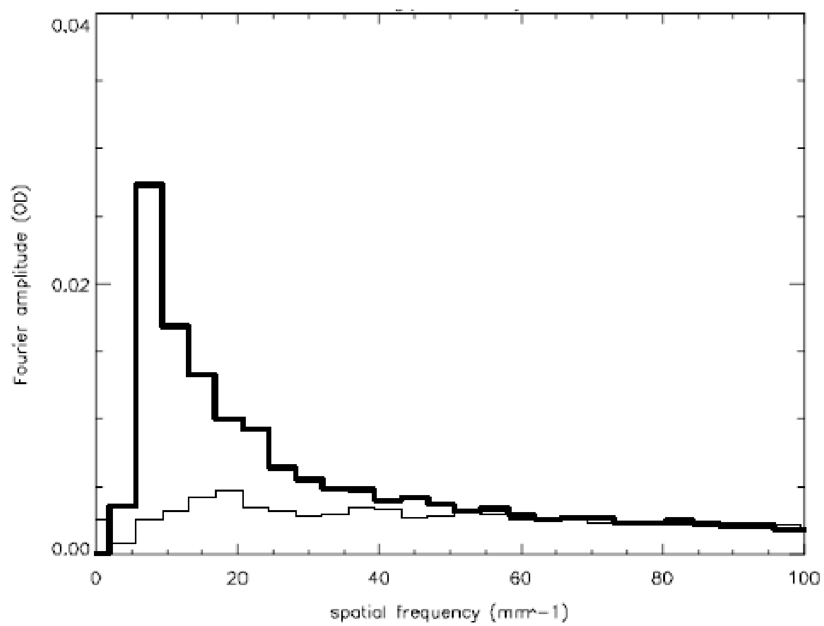
First Rayleigh-Taylor & Richtmyer-Meshkov instability measurements in laser driven planar targets on the OMEGA-EP laser

Face-on x-ray radiograph of the first RTI/RMI planar experiments on OMEGA-EP



1.63-ns

Fourier spectrum of the first RTI/RMI planar experiments on OMEGA-EP



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Presented by: Jon Hager (LLE)

Summary/Conclusion

The first RTI and RMI planar experiments on OMEGA-EP were a useful tool in planning for future OMEGA-EP experiments.

- An un-modulated CH[125] foil was driven with a single OMEGA-EP beam at an intensity of 2×10^{14} W/cm^2 for 2.5-ns and backlight with a Sc[12.5] foil.

- System and diagnostic issues hindered the experiment, but useful results were still obtained.

- Modulations imprinted by the OMEGA-EP beams grew significantly in the Sc[12.5] backlighter.

- Future experiments on OMEGA-EP will require beam smoothing, longer pulse lengths, and higher beam energies.

Introduction to the Rayleigh-Taylor instability

- **Rayleigh-Taylor Instability (RTI):**
  - **–Instability at the interface of fluids with different densities when a lighter fluid supports a heavier fluid.**
  - **–In ICF, RTI occurs during the acceleration and deceleration phases of the implosion.**
  - **–Modulations grow exponentially early in time, then grow linearly after reaching the saturation level ($Z_k=\lambda/10$) with the growth rate given by:[1]**

$$\gamma_{RT} = \alpha\sqrt{\frac{k \cdot g}{1 + k \cdot L_m}} - \beta \cdot k \cdot V_a \quad (2)$$

Variable	Description
α	Constant
β	Constant
k	Modulation wave number
g	Interface acceleration
V_a	Ablation velocity
L_m	Density scale length

Introduction to the Richtmyer-Meshkov Instability

- **Richtmyer-Meshkov Instability (RMI):**
  - **Instability at the modulated interface of two fluids when a shock wave crosses the interface.**
  - **In ICF, the RMI seeds modulations for the faster growing RTI as well as contributing to turbulent mixing between the capsule's fuel and shell.**
  - **Modulation evolution in the linear and non-linear regime can be characterized by the expression:** [3]

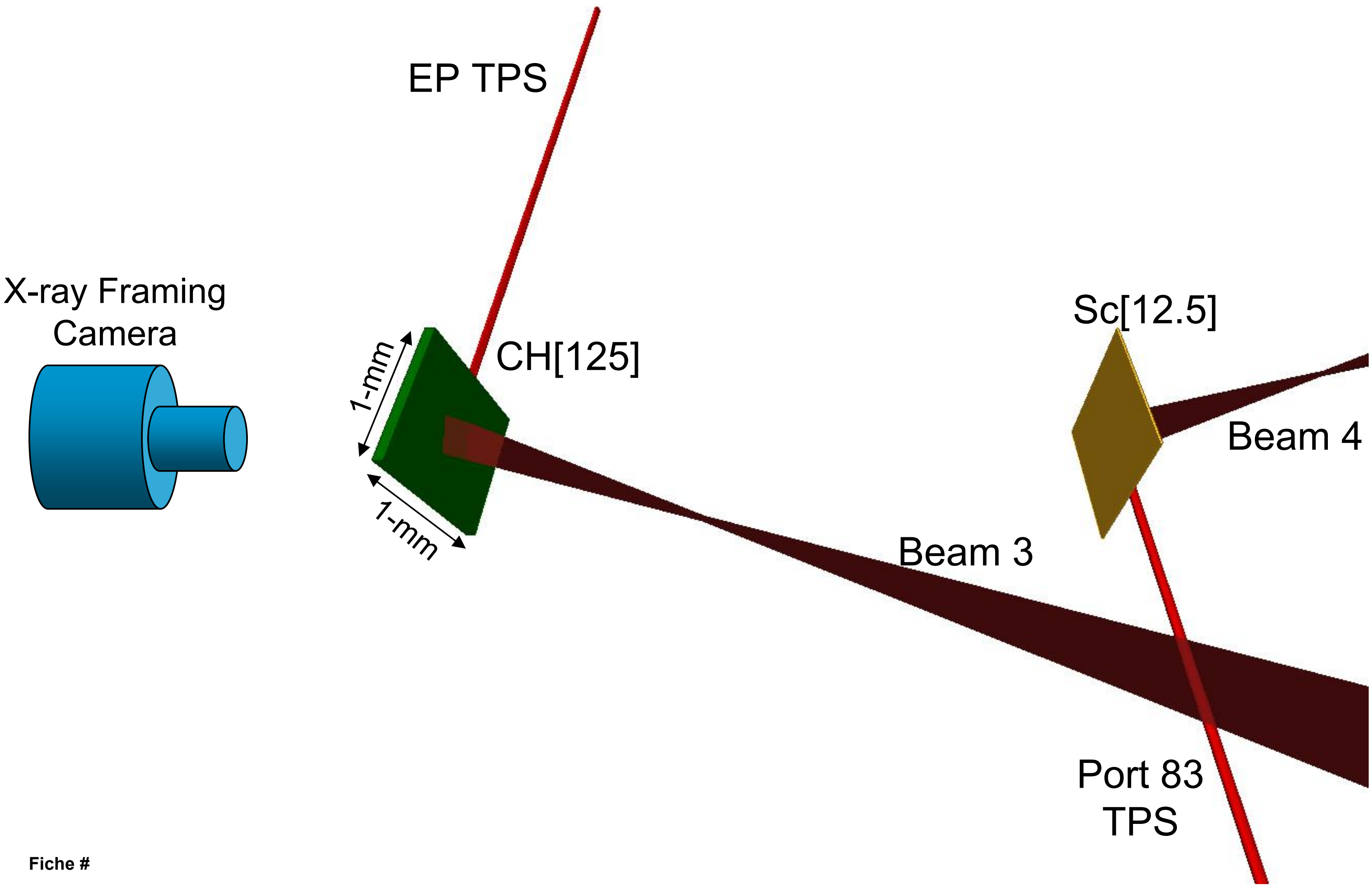
$$U(t) = U_0 \frac{1 + B \cdot t}{1 + D \cdot t + E \cdot t^2}$$

$$B = U_0 \cdot k \qquad D_{b/s} = (1 \pm A) U_0 \cdot k$$

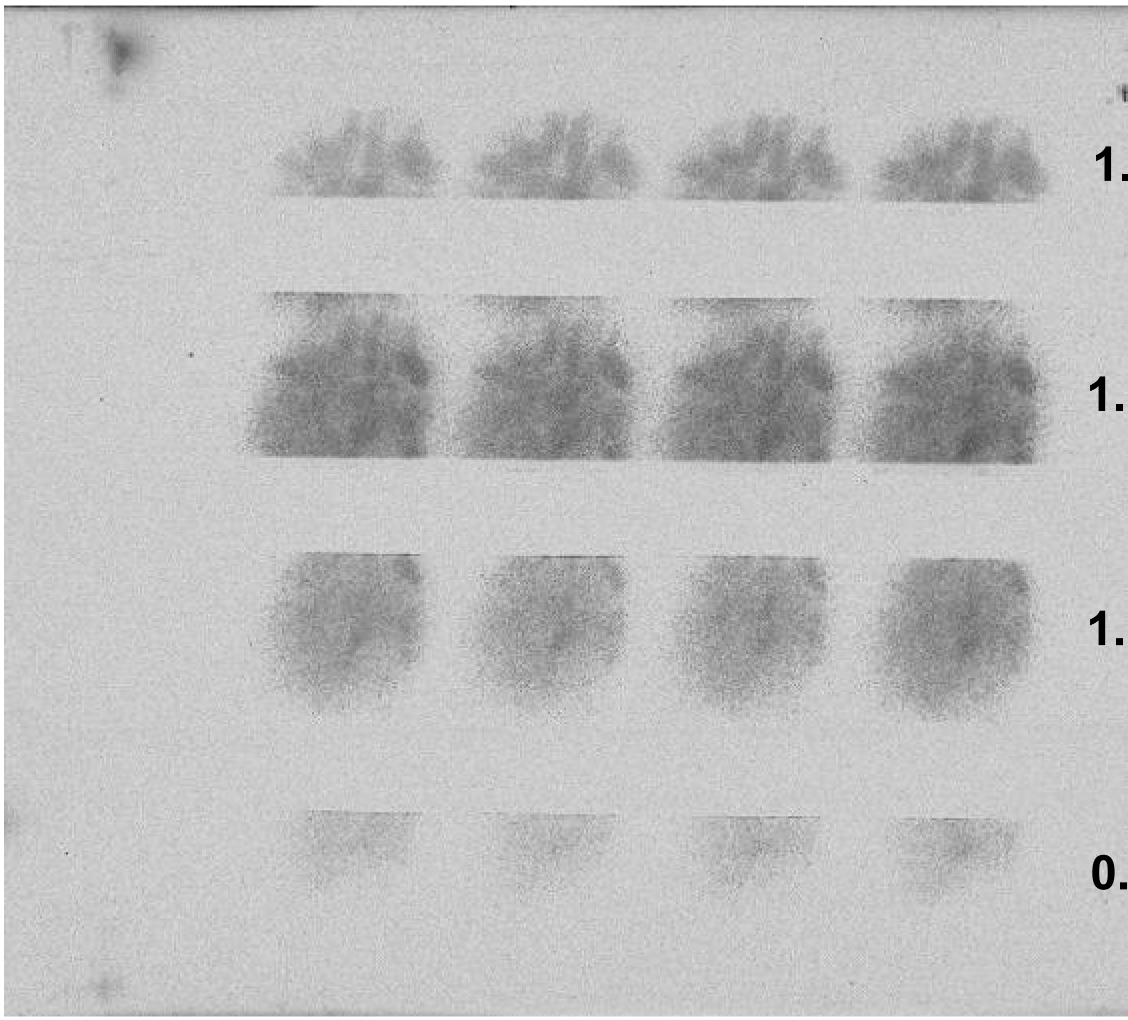
$$E_{b/s} = \left[\frac{(1 \pm A)}{(1 + A)} \right] \times \left(\frac{1}{2} \cdot \pi \cdot C \right) U_0^2 k^2$$

Variable	Description
U	Modulation velocity
k	Modulation wave number
A	Constant (Atwood Number)
C	Constant
U_0	Richtmyer initial velocity
b/s	+ is for a **b**ubble, - is for a **s**pike

On OMEGA-EP, an un-modulated CH[125] foil was driven at an intensity of $2\times10^{14}\ W/cm^2$ for 2.5-ns and backlight by a Sc[12.5] foil.

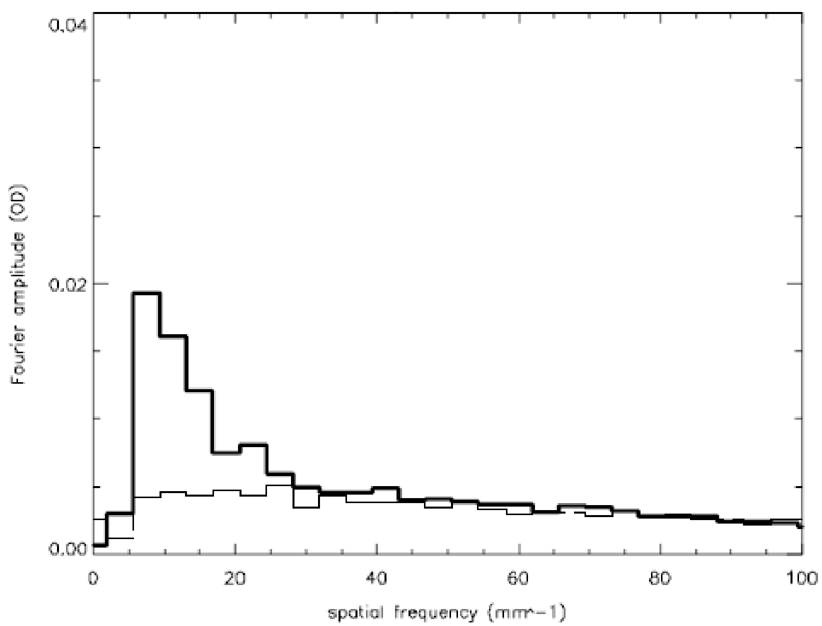


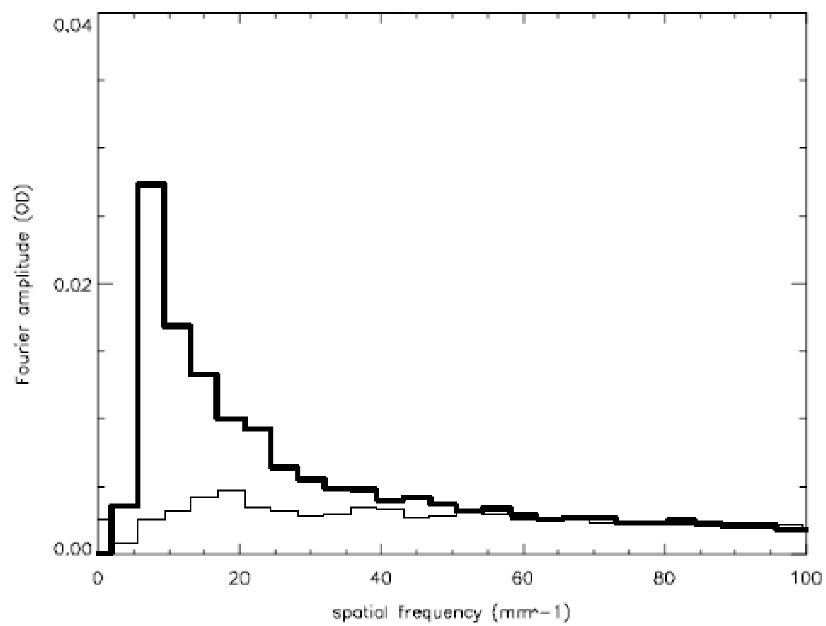
Face on x-ray radiography of a CH[125] target backlight by a Sc[12.5] foil showed significant modulation growth in the backlighter.

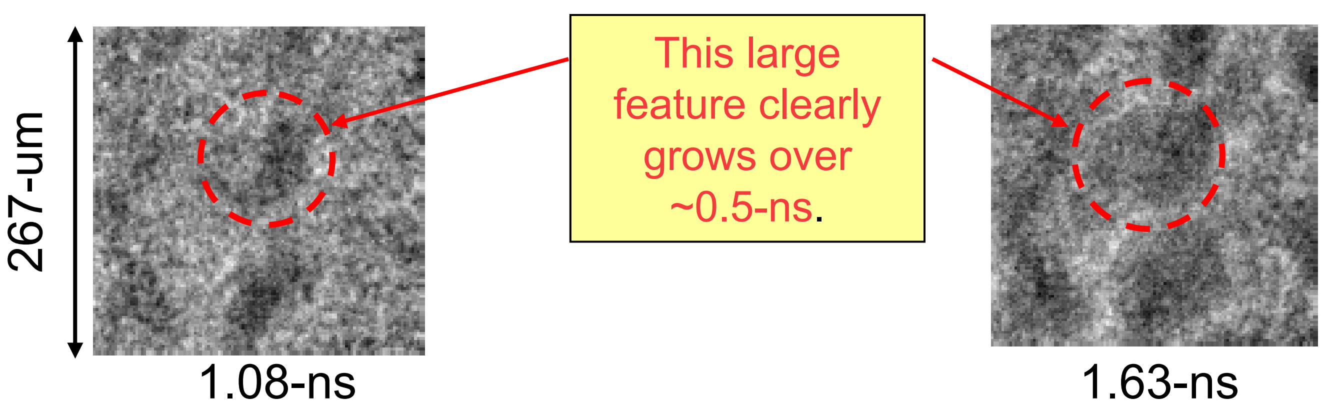


Features imprinted by the drive beam grow much faster than anticipated for a drive target of this thickness. A future shot was planned using only the backlighter to explore whether the growth was occurring in the target, backlighter, or both.

Modulation growth was dominated by the Sc[12.5] backlighter foil, instead of the CH[125] drive target.







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A misaligned pinhole array hindered this Sc[12.5] ‘backlighter only’ shot, but useful data was recovered.

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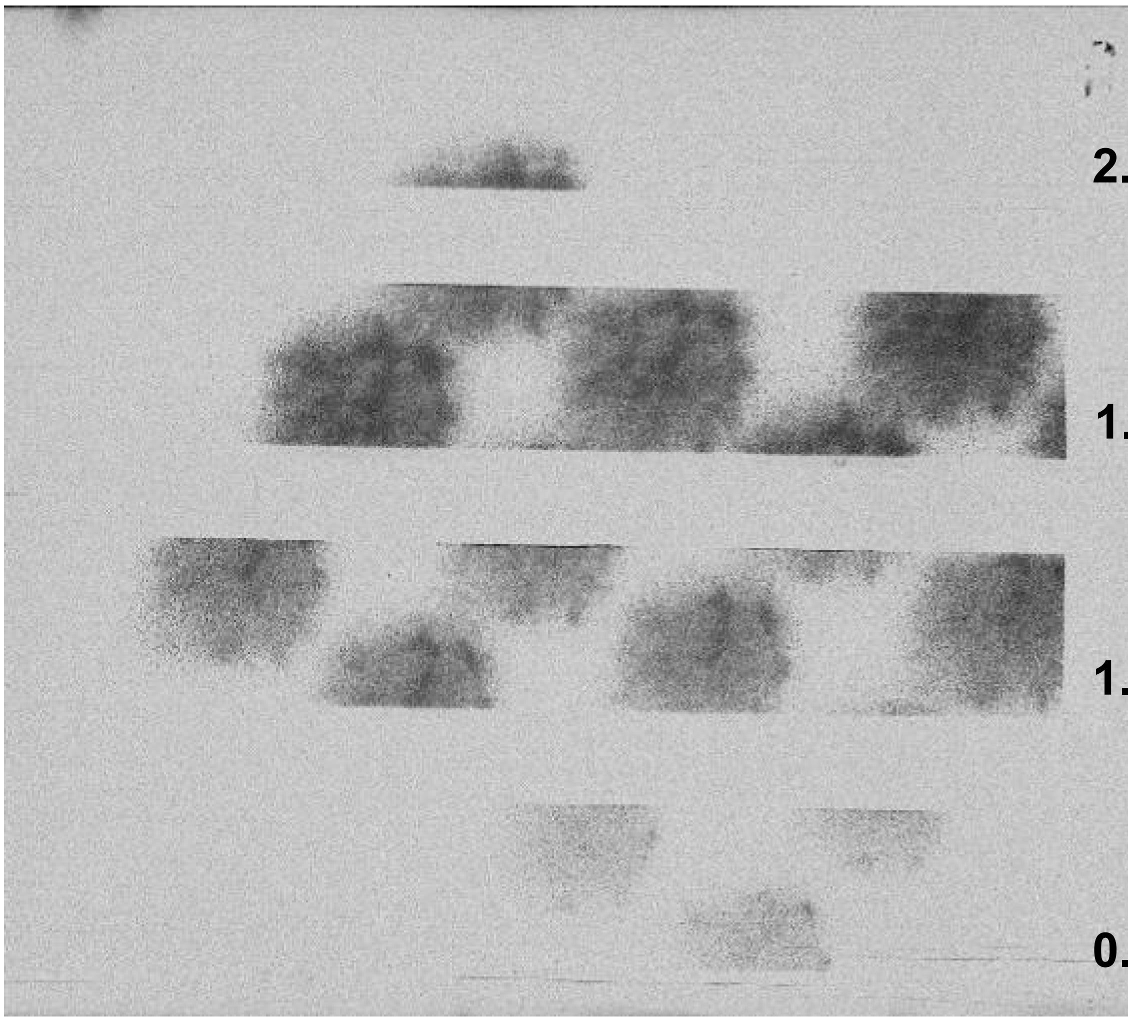

This ‘backlighter only’ shot shows similar results to the previous shot that used both the CH[125] target and Sc[12.5] backlighter. Unfortunately, the pinholes we not properly installed, but the data indicates that the majority of the growth is occurring in the backlighter.

Large scale features are also observed in the Sc[12.5] backlighter foil only experiment.

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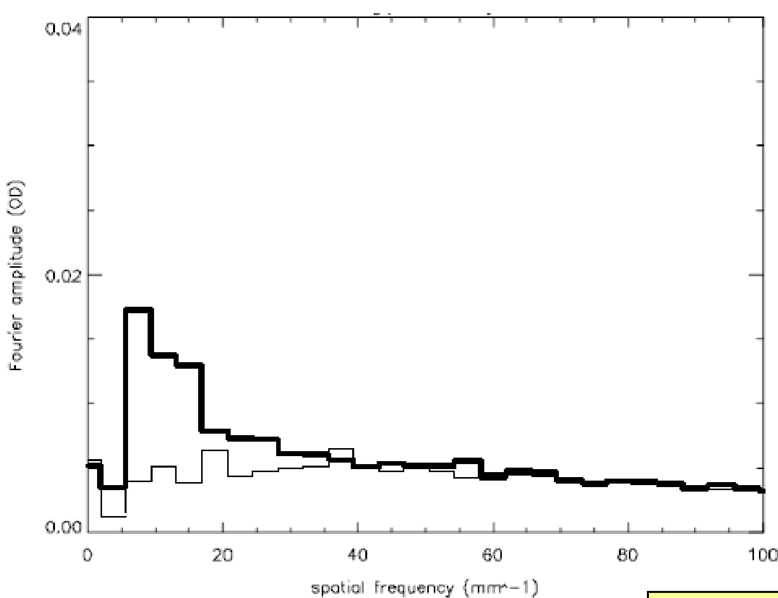
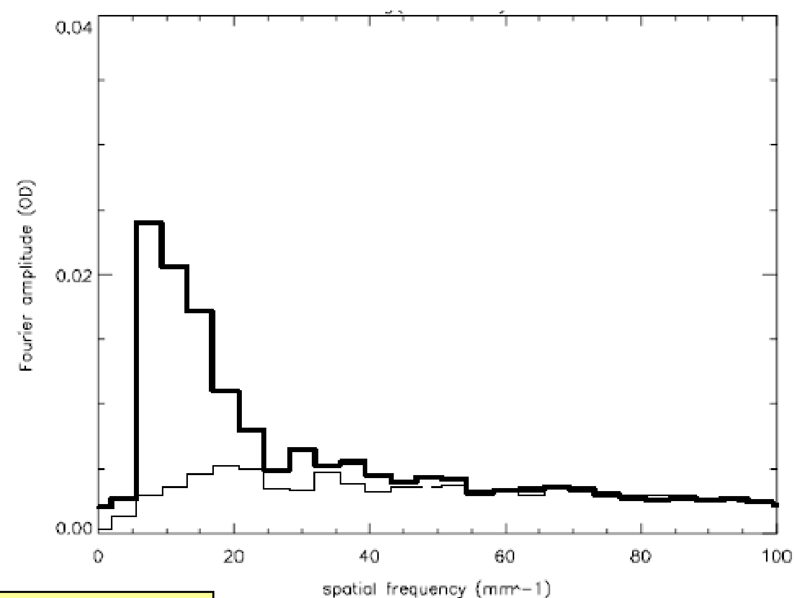
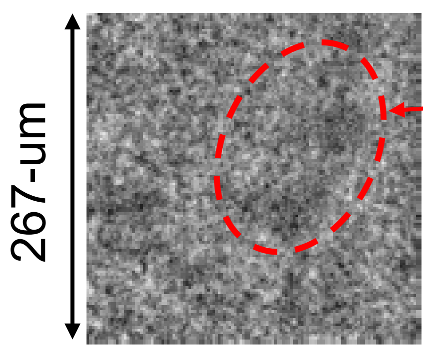
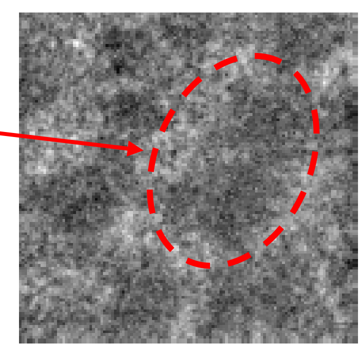






1.03-ns

Again, a large feature clearly grows over ~0.5-ns, showing significant modulation imprinting and growth in the backlighter.



1.53-ns

Overall, the shot day was very challenging, but useful data was obtained.

- The OMEGA-EP pulse length was inconsistent, compromising some of the data.
- Problems with the x-ray framing camera also compromised some of the data:
  - Timing was inconsistent – compromised data when combined with reduced pulse length of OMEGA-EP laser.
  - The framing camera film package was damaged while under vacuum, and exposed during the recovery process on 1 shot.
  - The pinhole array was improperly installed for 1 shot, compromising data on 2 of the 4 framing camera strips.
- Three targets shots were taken, with useful data obtained on 2 of the 3 shots.

Future RTI and RMI experiments on OMEGA-EP will require beam smoothing, longer pulse lengths (10-ns), and higher energies (5-kJ).

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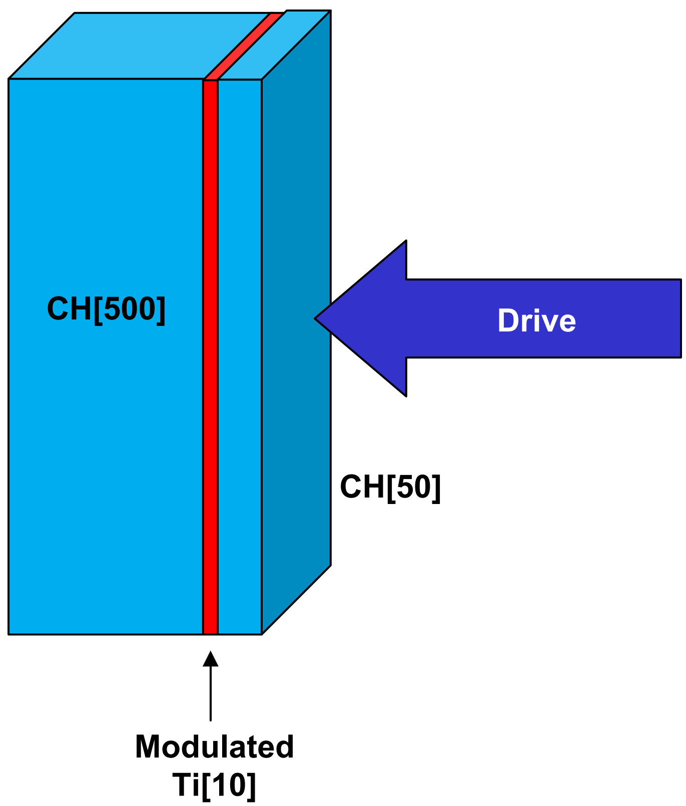
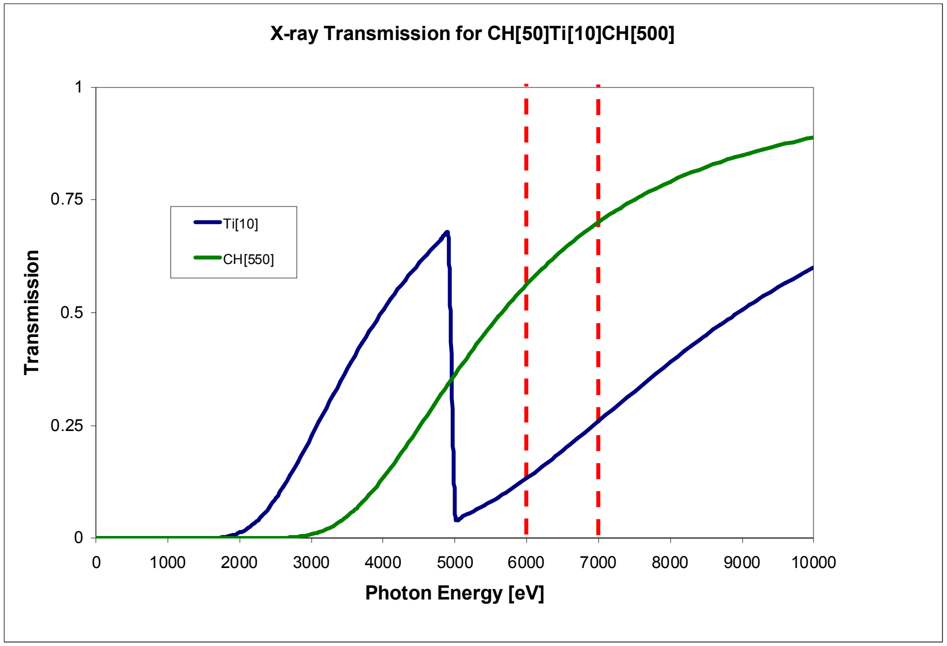
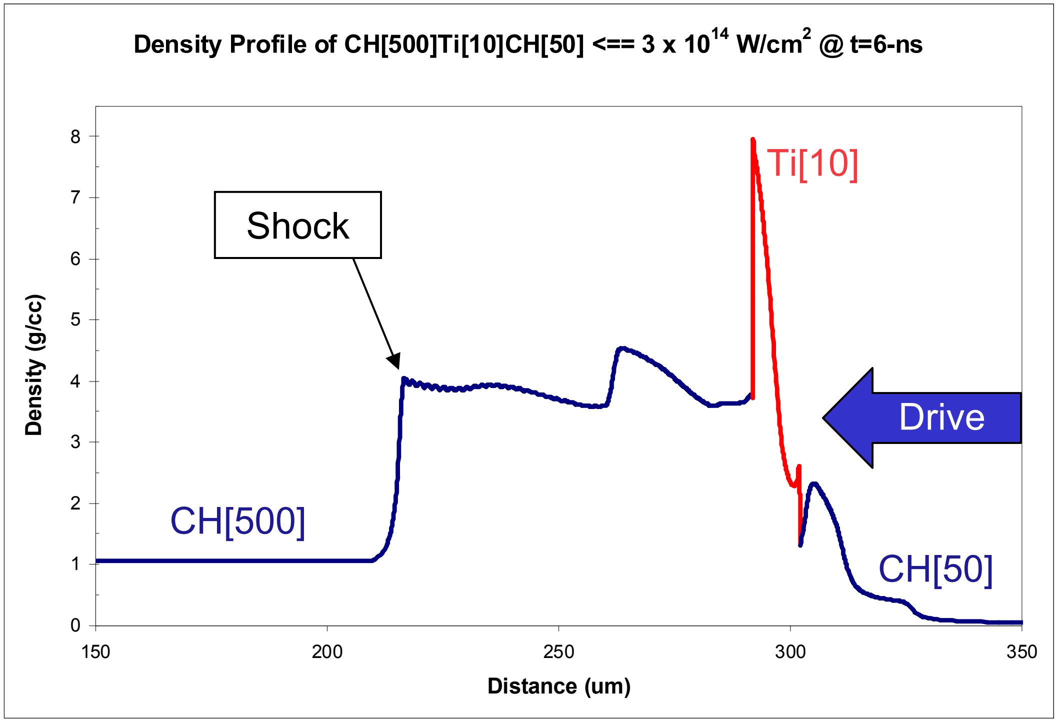
Proposed RMI Target Design

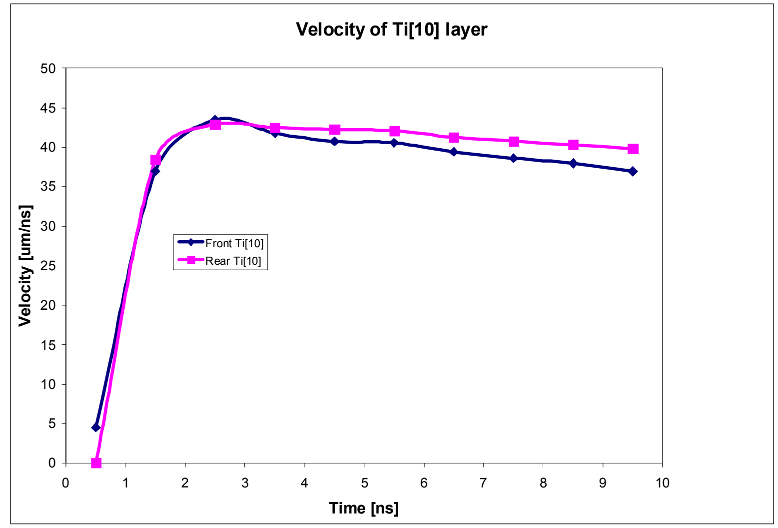


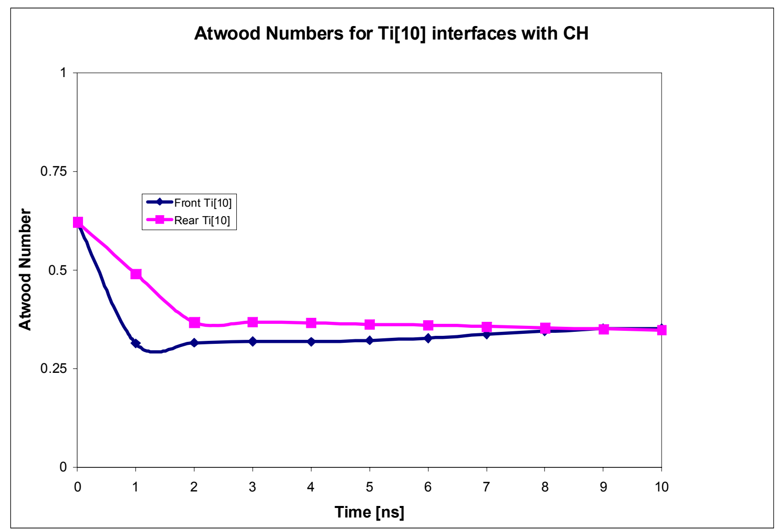


- 10-ns drive with an intensity of ~ 3 x 10^{14} W/cm^2
- 6-7 keV x-rays will radiograph the modulated Ti[10] layer.

LILAC simulation results show the Ti[10] layer travels at nearly constant velocity after the initial shock.

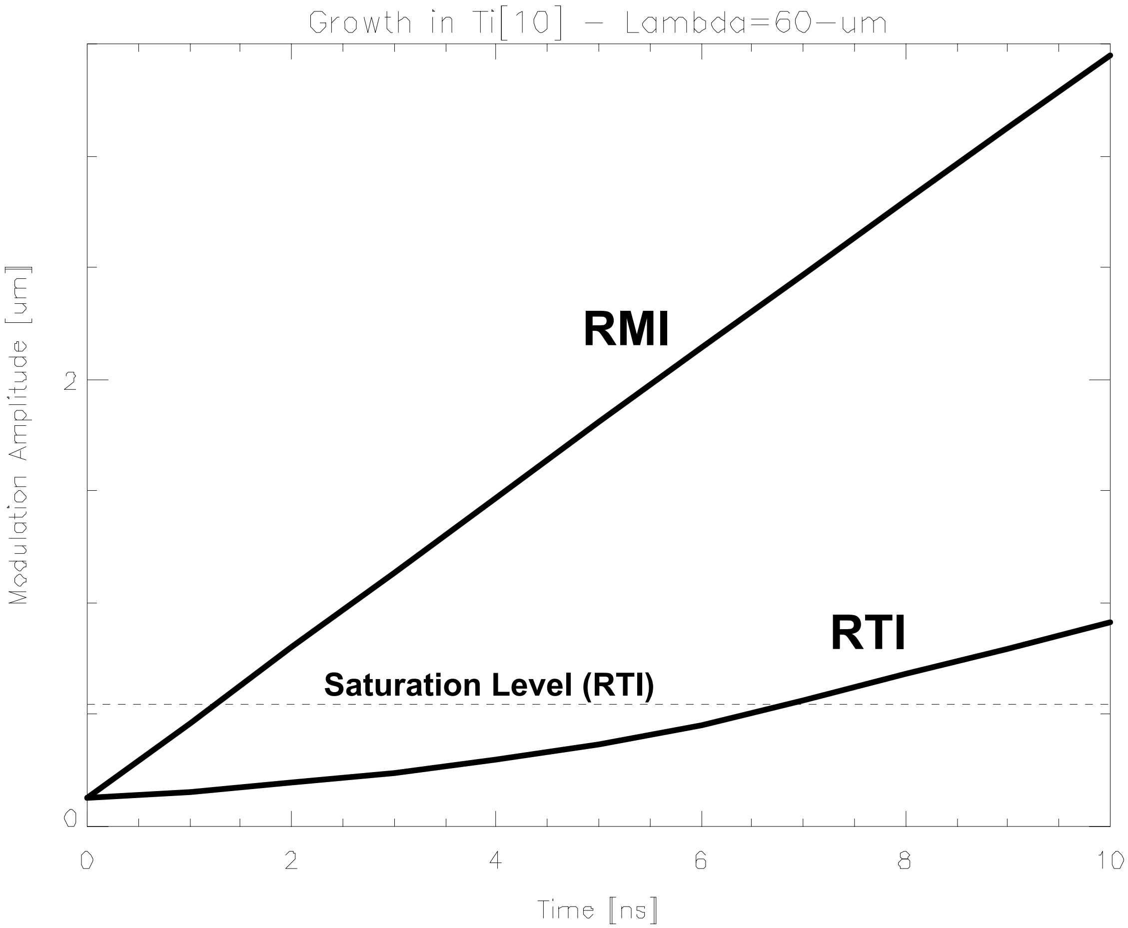






These conditions are ideal for experimentally measuring modulation growth due to the RMI independently from the RTI that typically dominates ICF instability experiments.

Low target acceleration minimizes the effect of RT growth, allowing the RMI to dominate.



Conditions from LILAC simulation:

Variable	Value
a_0	0.125 - µm
λ	60 - µm
g	3.6 - µm/ns^2
A	0.35
ΔU	36.9 - µm/ns

Collaborators and References

- **Collaborators**
  - **V. Smalyuk, I. Igumenshchev, D. D. Meyerhofer, T. C. Sangster**
- **References**

1. S. W. Haan. Physical Review A, **39**, 5812 (1989).
2. R. Betti. Physics of Plasmas, **5**, 1446 (1998).
3. O. Sadat. Physical Review Letters, **80**, 1654 (1998).